The as-HIP microstructures of the experimental alloys demonstrate the beneficial effect of high nitrogen contents on reducing the tendency to form sigma phase, and the detrimental effect of higher chromium and molybdenum contents on sigma phase formation, as indicated by the $T\sigma$ equation. High molybdenum, chromium, and nitrogen contents, all of which are beneficial for improved corrosion resistance, may be used if the alloy is properly balanced to avoid sigma phase formation when fully solution annealed.

Tension testing of the experimental materials clearly demonstrates the strong strengthening effect of higher nitrogen contents in austenitic stainless steels. The strengthening effect of nitrogen determined in these evaluations was about a 520 MPa increase per one wt % nitrogen, and is in good agreement with published data. (See, Speidel, High Nitrogen Steels 88.) Even with the high tensile strengths attained, the materials did not have reduced ductility when properly solution annealed.

Improved corrosion resistance has also been demonstrated in the experimental materials, particularly by virtue of the high factor for nitrogen in the PRE equation. Evaluations of the experimental and comparison HIP P/M materials indicate that PRE numbers in excess of about 55 are needed for best performance in ferric chloride and Green Death CPT and CCT evaluations.

Beyond the alloy design model, the present evaluations suggest that other corrosion resistant alloys produced by HIP P/M could be improved by utilizing higher nitrogen contents. The anticipated benefits for such modification to other corrosion resistant alloys are improved corrosion resistance, higher strength, and less tendency for sigma phase formation.

As is well known, the addition of copper up to about 3.5% to austenitic stainless steels improves corrosion resistance to reducing acids and thus copper may be added to the compositions in accordance with this invention. Boron, magnesium, and cerium are known to improve the hot workability of compositions in accordance with the invention.

Conclusions

An alloy design model has been used to develop austenitic stainless steels having a base chemical composition of Fe-6Mn-22Ni-25/28Cr-4/8Mo-0.6/0.9N. Evaluations of these materials, produced by HIP P/M, meet the model design criteria of having a fully austenitic microstructure, high yield strength, a minimum PRE of 50, a $T\sigma$ of less than 1232° C., a P_{N2} at 1600° C. of 500 kPa or more, and a cost factor of about 0.6 compared to UNS N10276. The following conclusions are based on evaluations of the experimental alloys produced by the design model, and comparison with other HIP P/M corrosion resistant alloys.

1. Gas atomization P/M can be used to produce nitrogen contents substantially higher than the equilibrium content predicted by existing thermodynamic models.
2. The yield strength of austenitic stainless steels increases with increasing nitrogen content, and high ductility and impact strength can be maintained with proper annealing.
3. HIP P/M highly alloyed austenitic stainless steels may contain undesirable precipitates after slow cooling from the HIP temperature, but a fully austenitic microstructure can be attained by using proper solution annealing temperatures. Nitrogen is a particularly useful alloying element in this regard, as it is a low cost austenite forming element which reduces the tendency for sigma phase formation.
4. The corrosion resistance of austenitic stainless steels, evaluated in ferric chloride and Green Death solutions, increases with increasing PRE number. High nitrogen steels, by virtue of the high PRE factor for nitrogen, exhibit excellent performance in these tests.
5. PRE numbers of 55 or greater are required for best performance in ferric chloride and Green Death test solutions.
6. High nitrogen austenitic stainless steels exhibit higher strength, with equivalent or better corrosion resistance than UNS N10276 in many environments, but with an alloy cost factor of about 0.6.

What is claimed is:

1. A consolidated, fully dense, high yield strength, austenitic stainless steel article produced from nitrogen gas atomized prealloyed particles, said article having a PRE greater than 55 and a $T\sigma$ not greater than 1232° C.

2. The article of claim **1**, having not less than 0.7 weight percent N.

3. The article of claim **1**, having greater than 0.7 weight percent N.

4. The article of claim **1**, having 0.8 to 1.1 weight percent N.

5. The article of claim **1**, having greater than 0.8 to 1.1 weight percent N.

6. A high yield strength, austenitic stainless steel, consisting essentially of, in weight percent, a maximum of 0.08 C, 0.5 to 12.5 Mn, 20 to 29 Cr, 17 to 35 Ni, 3 to 10 Mo, greater than 0.7 N, up to 1.0 Si, up to 0.02 B, up to 0.02 Mg, up to 0.05 Ce, and balance Fe.

7. The steel of claim **1**, consisting essentially of, in weight percent, not more than 0.03 C, 5.0 to 12.5 Mn, 24 to 29 Cr., 21 to 23 Ni, 4 to 9 Mo, 0.8 to 1.1N, 0.2 to 0.8 Si, and balance Fe.

8. The steel of claim **7**, having greater than 0.8 to 1.1N.

9. A high yield strength, austenitic stainless steel having a PRE greater than 55, $T\sigma$ not greater than 1232° C., and consisting essentially of, in weight percent, a maximum of 0.08 C, 0.5 to 12.5 Mn, 20 to 29 Cr, 17 to 35 Ni, 3 to 10 Mo, greater than 0.7N, up to 1.0 Si, up to 0.02 B, up to 0.02 Mg, up to 0.05 Ce, and balance Fe.

10. The steel of claim **9**, consisting essentially of, in weight percent, not more than 0.03 C, 5.0 to 12.5 Mn, 24 to 29 Cr, 21 to 23 Ni, 4 to 9 Mo, 0.8 to 1.1N, 0.2 to 0.8 Si, and balance Fe.

11. The steel of claim **10**, having greater than 0.8 to 1.1N.

12. A consolidated, fully dense, high yield strength, austenitic stainless steel article produced from nitrogen gas atomized prealloyed particles, said article having a PRE greater than 55, $T\sigma$ not greater than 1232° C., and consisting essentially of, in weight percent, a maximum of 0.08 C, 0.5 to 12.5 Mn, 20 to 29 Cr, 17 to 35 Ni, 3 to 10 Mo, not less than 0.7N, up to 1.0 Si, up to 0.02 B, up to 0.02 Mg, up to 0.05 Ce, and balance Fe.

13. The article of claim **12**, consisting essentially of, in weight percent, not more than 0.03 C, 5.0 to 12.5 Mn, 24 to 29 Cr, 21 to 23 Ni, 4 to 9 Mo, 0.8 to 1.1N, 0.2 to 0.8 Si, and balance Fe.

14. The article of claim **13**, having greater than 0.8 to 1.1N.

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